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Air Transport of California Strawberries:

Pallet Covers To Maintain Modified Atmospheres and Reduce Market Losses

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Air Transport of California Strawberries: *Pallet Covers to Maintain Modified Atmospheres and Reduce Market Losses*

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SUMMARY

Various types of pallet covers were tested as a means of maintaining high carbon dioxide (CO_2) atmospheres during air transport of California strawberries. The use of dry ice with covers that provided an effective gas barrier resulted in atmospheres with 20 percent or higher concentrations of CO_2. Both curtain-coated fiberboard and heat-shrunk polyethylene covers were effective.

Berry temperatures in the top layers of pallets averaged about 38° F. at shipping point and 50° at destination; respective temperatures in the middle layers averaged 39° and 42°. Ambient temperatures averaging 64° at the origin airport and 58° on the plane contributed to the rise in fruit temperature.

Relative humidity on the plane was generally about 11 to 12 percent.

Time from shipping point to wholesale delivery averaged about 13 hours for nonstop flights in which actual flying time was about 5 hours.

Shelf life of berries was increased by high CO_2 atmospheres, which reduce decay during marketing. Overall cutting and bruising injury of berries averaged about 4 percent.

BACKGROUND

Production of strawberries in California in 1969 was 268.8 million pounds, with a value of about $60.7 million. California produces about three-fourths of the total United States production of strawberries marketed as fresh fruit. Marketing of the crop starts in February and continues until rain or frost occurs, usually in November. About 202.4 million pounds of the California crop were shipped fresh and about 149.6 million pounds were shipped out of State. Of the out-of-State shipments, 38 million pounds were by air, 5.6 million pounds by expedited piggyback freight, and 115.5 million pounds by truck. No berries were shipped by railway express for the first time in many years. Most truck and piggyback shipments go to markets west of Chicago, and most air shipments go to markets east of there. The value of strawberries shipped out of State was about $37.4 million in 1969.

Surveys in the New York and Chicago markets indicate that losses in California berries due to decay and physical damage average from 20 to 26 percent through the consumer level,[1] which would constitute a monetary loss of $7.5 to $9.7 million. These losses could be reduced by better control of transit temperatures, improved packaging, modified atmospheres, and other decay control measures.

Strawberry temperatures during air transport are generally higher than during surface transportation, because of the lack of refrigeration (*6*, *7*, *8*, *9*, *10*, *11*)[2] during a large part of the transit period. Previous research has shown that straw-

[1] Personal communication from J. Kaufman and L. Beraha, investigations leaders, Market Pathology Laboratories, U.S. Department of Agriculture.

[2] Italic numbers in parentheses refer to Literature Cited, p. 10.

berries suffer about twice as much decay at 55° F. as at 34° and about four times as much at 70° as at 34° (*6*). Other types of deterioration show a similar temperature relation. Modified atmospheres with 20 percent or higher carbon dioxide (CO_2) levels have been shown to reduce the activity of decay-causing organisms (*1*, *2*, *3*, *12*, *13*) and also to reduce losses from decay under conditions of air transport (*9*, *10*, *11*).

An effective method of maintaining high CO_2 atmospheres in transit was needed. Since strawberries are commonly palletized before shipment, research on various types of pallet covers was conducted to determine their effectiveness as gas barriers, their effect on transit temperatures, and their consequent influence on decay of berries shipped in them.

MATERIALS AND METHODS

Strawberries for air shipment are usually palletized in units of 60, 72, or 84 flats. Most pallet loads of berries are covered with a fiberboard sleeve and cap; some, however, are shipped without covers in early spring because of the cool weather.

Test Packages

Strawberries for test packages were selected at the receiving dock of the precooling plant for uniform quality, size, maturity, and field of origin. The test flats of berries were placed in the top and middle layers of each pallet load of fruit tested.

Pallet Covers

Four types of pallet covers were tested: (1) A sleeve and cap made of corrugated fiberboard, (2) a sleeve and cap made of "curtain-coated" fiberboard, with the seams taped, (3) a sleeve and cap made of "curtain-coated" fiberboard, with a double-fold and strapped closure, and (4) a 3-mil-polyethylene cover that was heat-shrunk over the pallet load of berries. The floor of the pallet used with each type of pallet cover was provided with a covering of the same material used in the sleeve and cap.

Curtain-coated fiberboard is made by passing the fiberboard beneath a flowing curtain of molten waxes and resins. The curtain consists of a blend of paraffin, polyethylene, and other resins, heated to 225° to 240° F. The process results in a uniform coating of the fiberboard; the thickness of the coating depends upon the speed at which the fiberboard passes beneath the curtain and also upon the flow rate of material in the curtain.

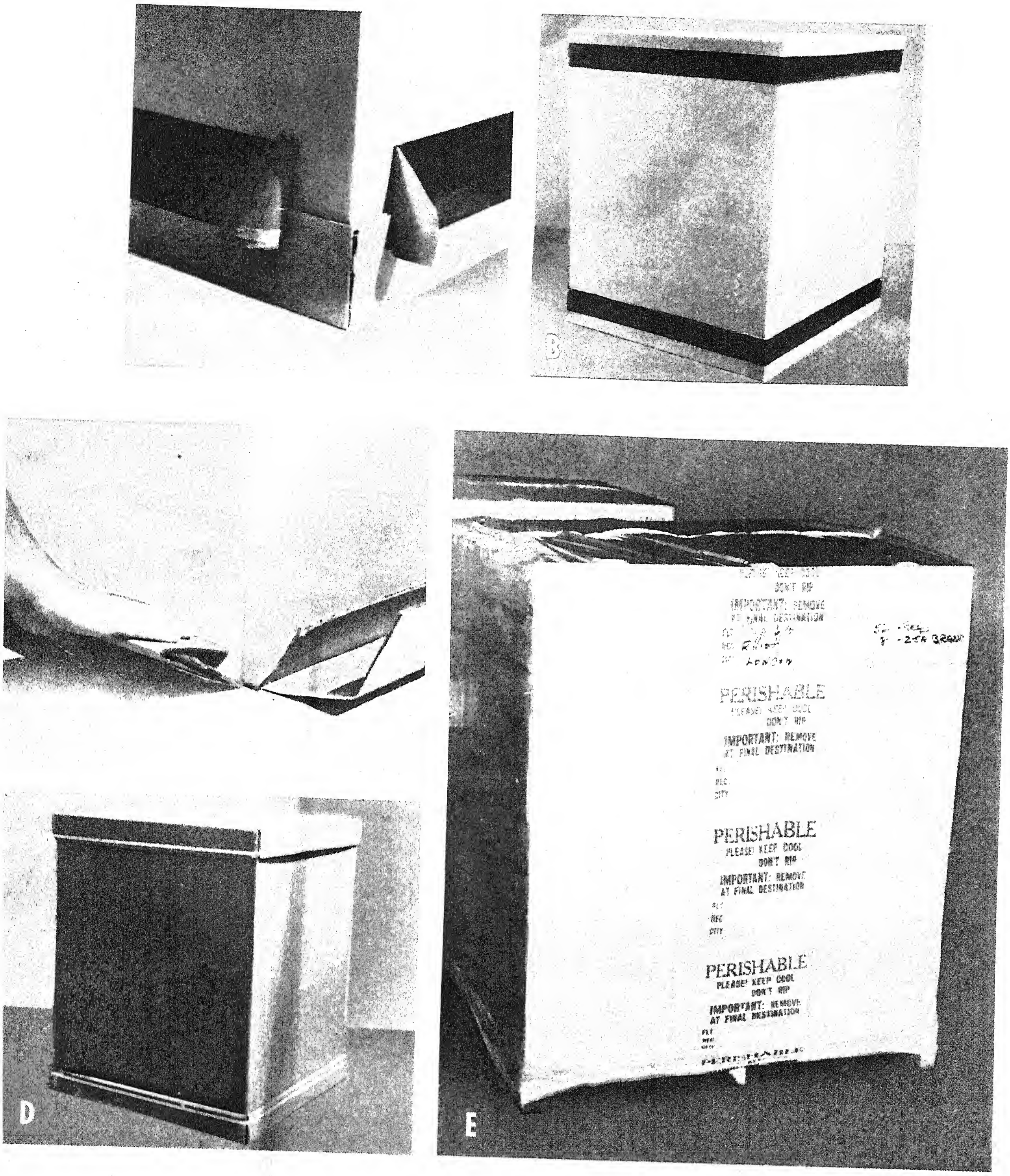
Closures for curtain-coated pallet covers were made either by (1) taping the bottom and cap to the sleeve with a 4-inch polyethylene pressure-sensitive tape (fig. 1, *A*, *B*) or (2) folding the cap and bottom of the pallet cover tightly over the sleeve and strapping them in place (fig. 1, *C*, *D*).

The polyethylene covers were in the form of large bags that were pulled down over the pallet loads (fig. 1, *E*). The closure was at the bottom where the bag overlapped the margins of a sheet of polyethylene previously placed between the wooden pallet and the fruit stacked upon it. The cover was heat-shrunk with a blast of hot air that pulled the film tightly against the pallet load and also drew the bag and base covering tightly together.

All fruit was precooled before applying the covers and 6 pounds of dry ice (as a source of CO_2) was placed in an empty berry flat in the top layer of the pallet load. The dry ice was wrapped in heavy paper to slow the rate of sublimation, and an additional empty flat was set below the one with the ice to prevent freezing of adjacent fruit.

Atmosphere Sampling

A plastic tube was inserted into the pallet load to measure carbon dioxide and oxygen levels at intervals in transit. The place at which the tube passed through the pallet cover was carefully taped to prevent leakage of gases. Atmosphere composition was determined with an Orsat-type analyzer. In unaccompanied tests, an atmosphere analysis was made at the airport before departure and also on arrival at the destination airport. In accompanied tests, additional analyses were made in the plane and at transfer or stopover points.



PN–1924 ; PN–1925 ; PN–1926 ; PN–1927 ; PN–1928

FIGURE 1.—*A* and *B*, Curtain-coated pallet cover with taped closure; *C* and *D*, curtain-coated pallet cover with fold-strap closure; *E*, shrink-wrap polyethylene pallet cover.

Temperature Measurement

Transit temperatures of berries were measured with thermocouples inserted in berries in the middle and top layers of each pallet of fruit. In accompanied tests, temperatures were read on a potentiometer at intervals during handling and transit. In unaccompanied tests, temperatures were read only at shipping point, at the origin airport, and at destination; in addition, recording thermometers were placed in empty berry flats in the top and middle layers of each pallet.

Relative Humidity Measurement

Relative humidity in the cabin of the airfreighter was measured with a sling psychrometer. Wet- and dry-bulb readings were converted to relative humidity by the use of a psychrometric chart corrected for a 5,000-foot altitude. Cabin pressure was maintained at a level approximately equivalent to this altitude.

Commercial Handling

Test shipments were handled in transit according to conventional commercial procedures. Information on the test shipments is given in table 1. The pallets were conveyed from shipping points to the airports in refrigerated trucks. At the airport the pallets were either placed on a master airline pallet and covered with a cargo net or placed in a fiberglass-covered igloo. The berry pallets were handled in units of six. After "unitizing," the berries were set in a holding area to await loading on the plane.

In accompanied shipments, the test pallets were placed in the forward position in the cargo compartment of the airfreighter so that they were accessible for temperature and atmosphere readings in transit. Thermocouple leads and gas sampling tubes were passed through a safety net between the cargo compartment and a vestibule behind the pilot's cabin; instruments were then attached to the lines. This procedure permitted the collection of data in the vestibule. In unaccompanied shipments, the test pallets were placed at random positions within the airfreighter, according to load-balancing requirements of the airline.

At terminal airports the individual berry pallets were transferred to a refrigerated truck that hauled them to the wholesale market.

Evaluation of Test Packages

Test flats of berries were recovered at the wholesale market and taken by automobile to the U.S. Department of Agriculture's Market Pathology

TABLE 1.—*Air shipping tests with California strawberries*

Date	Carrier and flight No.[1]	Shipping origin in California [2]	Stops or transfers en route	Destination [3]	Accompanied
1968					
Mar. 28	AAL 842	Anaheim	None	New York	Yes
Apr. 3	TWA 600	do	None	do	Yes
June 12	UAL 9972	Watsonville	None	do	Yes
June 19	UAL 9974	do	Cleveland	do	Yes
Aug. 28	AAL 868	do	None	do	Yes
Sept. 17	UAL 9972	do	None	do	Yes
Oct. 1	UAL 9994	do	Chicago	Philadelphia	Yes
Oct. 9	UAL 9972	do	None	New York	Yes
1969					
June 3	UAL 2872	do	None	do	No
Sept. 9	AAL 828	do	None	do	No
Oct. 1	UAL 2874	do	Cleveland	do	No
Oct. 8	UAL 2982	do	None	Chicago	Yes

[1] AAL, American Airlines; TWA, Trans World Airlines; and UAL, United Airlines. These are regularly scheduled cargo flights.

[2] Flights for shipments from Anaheim originated at Los Angeles International Airport; those from Watsonville originated at San Francisco International Airport.

[3] All shipments destined for New York arrived at John F. Kennedy International Airport.

Laboratory for detailed examination. Separate lots of berries were examined on arrival and after holding 1 day and 2 days at 60° F. The berries were examined individually for decay, cuts and bruises, and other defects. Data for decay and cuts and bruises were treated statistically by analysis of variance. Data on atmosphere modification were averaged for test pallets in which CO_2 levels were 20 percent or higher and for camparable check lots without CO_2. Transit temperatures are averages for nonstop flights.

RESULTS

Atmospheres in Transit

Carbon dioxide concentrations in the atmosphere during air transport of strawberries in three types of pallet covers are shown in figure 2. The CO_2 built up rapidly between shipping point and origin airport and approached a maximum by the time the first reading was taken on the plane. Carbon dioxide levels were slightly higher in intact shrink-wrap covers than in the coated-fiberboard covers. However, a number of the shrink-wrap covers were torn before reaching destination, which caused a loss of CO_2.

Oxygen levels within the pallet covers rarely were reduced below 15 percent; this level had no effect on the berries or decay organisms.

No atmosphere modification occurred in the uncoated fiberboard covers.

Temperatures in Transit

Berry temperatures in the top layers of the pallets averaged about 38° F. at shipping point and about 50° at the destination airport (fig. 3). The temperature rise was greatest during the 2½ hours at the origin airport, after which there was a

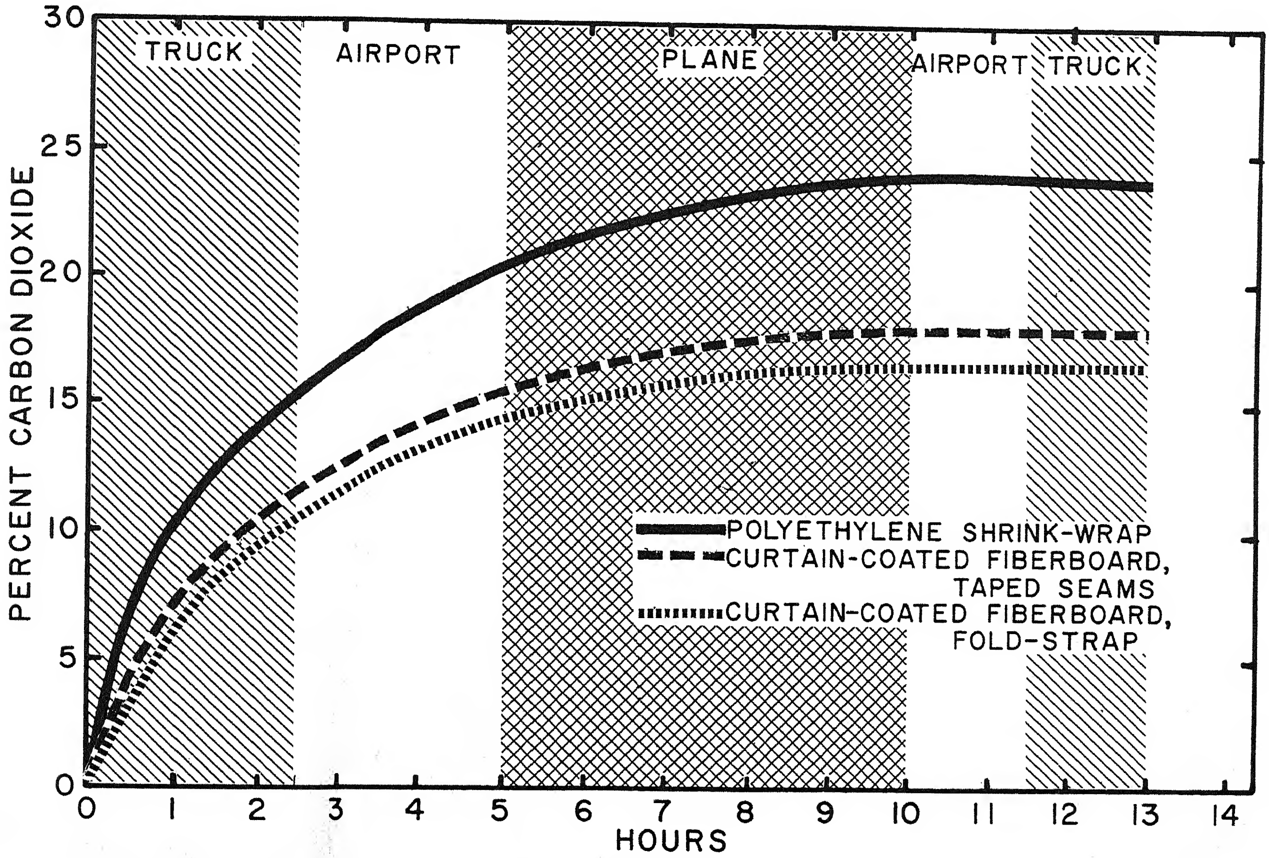


FIGURE 2.—Carbon dioxide modification during air transport of strawberries in three types of pallet covers.

gradual rise on the airfreighter. Most berries are carried in refrigerated trucks to the origin airport and from the terminal airport to the wholesale market, which prevents a temperature rise during these portions of the transit period.

Berry temperatures in the middle layers of the pallets averaged about 39° F. at shipping point and 42° at the destination airport (fig. 3).

A comparison of 1968 and 1969 tests (fig. 4) shows average temperatures of berries to be slightly lower in 1969—a reflection of the switch to forced-air precooling by the strawberry industry (*4*, *5*). Berries that start cooler usually remain cooler throughout transit than berries that are not precooled so well.

Ambient temperature averaged about 40° F. in trucks between shipping point and origin airport, 64° at the origin airport, and about 58° on the airfreighters. Temperatures at terminal airports also were about 58°, since most flights arrived early in the morning. Temperatures in refrigerated trucks between terminal airports and wholesalers also averaged about 40°.

Relative Humidity in Transit

Relative humidity in the aircraft during flight ranged from 10 to 20 percent, but generally was about 12 percent.

Time in Transit

Most strawberry shipments averaged about 13 hours from shipping point to delivery at the wholesale market (fig. 2). Nonstop flights from west to east coast generally required about 5 hours. In ad-

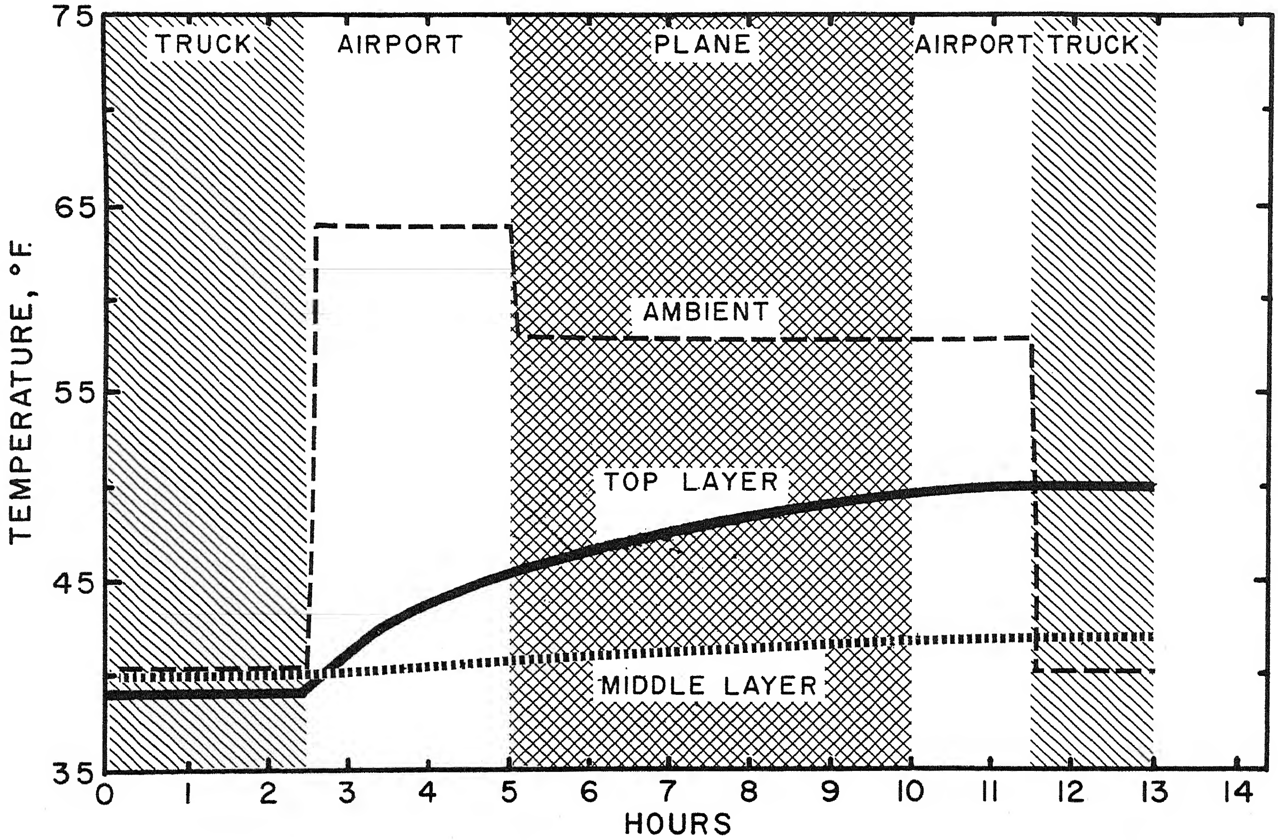


FIGURE 3.—Temperatures of strawberries in top and middle layers of strawberry pallets during air transport from California to Eastern U.S. markets.

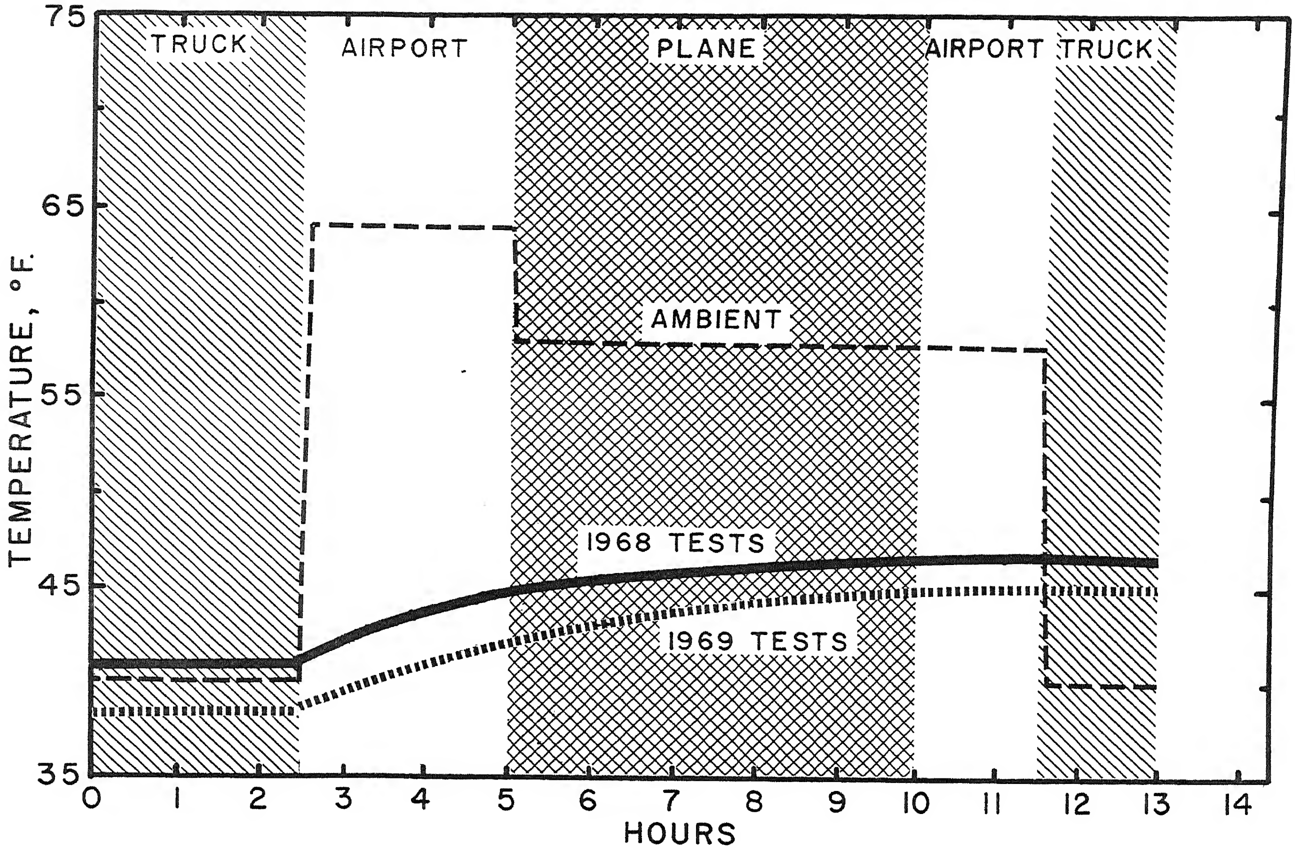


FIGURE 4.—Temperatures of strawberries during air transport from California to Eastern U.S. markets, 1968 and 1969.

dition, 4 hours were spent in airports and 4 hours in trucks. Thus, even with nonstop schedules, only about 40 percent of the total time in transit was spent on the plane, while 60 percent was spent during ground transportation and handling.

Decay

Strawberries shipped in pallet covers in which CO_2 levels were 20 percent or higher had 1.1 percent decay on arrival, 2.5 percent after 1 day, and 11.0 percent after 2 days at 60° F. (table 2). Berries shipped without CO_2 had 0.9, 3.6, and 18.4 percent decay, respectively, at these examinations. The beneficial effect of CO_2 was not evident immediately after transit (arrival examination), but the increased shelf life became apparent during holding at 60°.

Decay of berries in the top layers of the pallets averaged 6.6 percent and that in the middle layers averaged 5.9 percent. This difference was not great enough to be statistically significant.

Cutting and Bruising

Cutting and bruising of berries averaged 5.0 percent in the top layers of the pallets and 3.0 percent in the middle layers (table 3). Berries shipped in pallets with high CO_2 levels averaged 3.5 percent cutting and bruising; those with low CO_2 averaged 4.5 percent. If the CO_2 had sufficiently retarded ripening, less cutting and bruising would have been expected in the lots with high CO_2. However, differences in cutting and bruising due to position and atmosphere were not great enough to be statistically significant.

TABLE 2.—*Percentage decay in California strawberries shipped by air to Eastern U.S. markets*

Date of shipping	CO_2 atmosphere in transit [1]	Percentage decay of berries at indicated examination and position [2] in pallet load: Arrival, Top	Arrival, Middle	After 1 day, Top	After 1 day, Middle	After 2 days, Top	After 2 days, Middle	Mean atmosphere
1968								
Aug. 28	High	1.4	1.0	2.7	1.2	13.4	7.4	4.5
	Low	1.4	1.3	3.2	3.9	12.4	15.0	6.2
Sept. 17	High	.6	.3	1.7	1.4	17.2	10.7	5.3
	Low	.6	.9	1.8	1.8	31.5	39.5	12.7
Oct. 1	High	1.4	.6	1.8	2.6	7.0	5.6	3.2
	Low	.9	1.0	8.0	2.0	25.9	11.6	8.2
Oct. 9	High	2.1	.6	3.8	4.0	20.0	12.0	7.1
	Low	0	.8	1.0	5.8	17.0	12.0	6.1
1969								
June 3	High	1.4	0	2.5	3.6	12.5	10.9	5.1
	Low	.8	.6	3.8	7.1	22.8	21.4	9.4
Sept. 9	High	2.4	2.0	2.2	2.8	7.4	7.8	4.1
	Low	.7	2.3	2.2	2.8	2.3	9.7	3.3
Mean:								
High CO_2 × examination × position		1.5	.7	2.4	2.6	12.9	9.1	
Low CO_2 × examination × position		.7	1.1	3.3	3.9	18.6	18.2	
Mean: [3]								
High CO_2 × examination		1.1 a		2.5 a		11.0 b		4.9 a
Low CO_2 × examination		.9 a		3.6 a		18.4 c		7.6 a
Mean for examination [3]		1.0 a		3.0 a		15.0 b		

[1] High carbon dioxide atmosphere, 20 percent or higher; low carbon dioxide atmosphere, normal air.
[2] Means for top and middle layers are 6.6 percent and 5.9 percent, respectively, and do not differ significantly at 95-percent level.
[3] Means within a block followed by the same letter do not differ significantly at the 5-percent level.

TABLE 3.—*Cuts and bruises in California strawberries shipped by air to Eastern U.S. markets* [1]

Date of shipping	CO_2 atmosphere in transit [2]	Percentage cuts and bruises [3] of berries in— Top layer	Middle layer	Mean
1968				
Aug. 28	High	2.2	0.3	1.7
	Low	.7	2.1	1.4
Sept. 17	High	9.0	3.7	6.3
	Low	3.8	3.3	3.5
Oct. 1	High	3.1	2.5	2.8
	Low	3.1	1.9	2.0
Oct. 9	High	4.9	0	2.4
	Low	5.2	6.3	5.8
1969				
June 3	High	3.4	7.9	5.6
	Low	16.7	2.9	9.8
Sept. 9	High	3.0	1.8	2.4
	Low	4.5	4.0	4.2
Mean: [4]				
High CO_2 × position		4.3	2.7	
Low CO_2 × position		5.7	3.4	
Mean: [4]				
High CO_2				3.5
Low CO_2				4.5
Mean [4] for position		5.0	3.0	

[1] Berries rated for cuts or bruises at arrival examination only.
[2] High carbon dioxide atmosphere, 20 percent or higher; low carbon dioxide atmosphere, normal air.
[3] Cuts and bruises ⅜ in. or more in diameter.
[4] Differences in means not statistically significant.

DISCUSSION AND CONCLUSIONS

Modified atmospheres in which carbon dioxide levels were 20 percent or higher in transit were obtained in commercial strawberry shipments with either coated-fiberboard or shrink-wrap pallet covers. Supporting laboratory studies (*12*, *13*) have shown that rhizopus rot of strawberries is significantly reduced by CO_2 levels above 10 percent and that gray mold rot is significantly reduced at levels above 20 percent under simulated air transit and marketing conditions. No off flavors develop unless CO_2 levels are above 30 percent, and these disappear when the berries are placed in normal air for 24 hours (*2*). The shipping tests reported herein also show a reduction of decay with elevated CO_2 levels in the atmosphere.

Transit temperatures in these tests were somewhat lower than those observed in earlier tests (*7*, *8*, *9*). This improvement is due in part to the more widespread use of forced-air precooling by shippers and also to the increased number of nonstop freighter flights to eastern marketing areas. Forced-air cooling has resulted in lower average berry temperatures at shipping point and also in more uniformly low temperatures throughout the pallet than could be obtained with older cooling methods. Berries with lower temperatures at shipping point also have lower berry temperatures at destination than those not so well precooled (fig. 3). However, high temperatures in the top layers of fruit are still a problem.

Nonstop freighter flights eliminate the temperature rise in strawberries that previously occurred at transfers or stopovers en route. However, at an average cabin temperature of 58° F., a gradual warming of berries still occurs on the plane. The nonstop flights also contribute to a reduction in total transit time from shipper to wholesaler. This time averaged about 13 hours, compared with about 18 hours in earlier tests (*7*, *8*, *9*). Improved air schedules and faster precooling, together, permit delivery at the wholesale market on the morning after the day of harvest in California. Older precooling methods often required overnight holding at the precooling plant before shipment.

Relative humidity as low as 10 percent during flight would have a drying effect on berries and is an additional reason for protecting the fruit with pallet covers.

LITERATURE CITED

(1) COUEY, H. M., FOLLSTAD, M. N., and UOTA, M.
1966. LOW-OXYGEN ATMOSPHERES FOR CONTROL OF POSTHARVEST DECAY OF FRESH STRAWBERRIES. Phytopathology 56: 1339–1341.

(2) ——— and WELLS, J. M.
1970. LOW-OXYGEN OR HIGH-CARBON DIOXIDE ATMOSPHERES TO CONTROL POSTHARVEST DECAY OF STRAWBERRIES. Phytopathology 60: 47–49.

(3) FOLLSTAD, M. N.
1966. MYCELIAL GROWTH RATE AND SPORULATION OF ALTERNARIA TENUIS, BOTRYTIS CINEREA, CLADOSPORIUM HERBARUM, AND RHIZOPUS STOLONIFER IN LOW OXYGEN ATMOSPHERES. Phytopathology 56: 1098–1099.

(4) GUILLOU, RENE.
1960. COOLERS FOR FRUITS AND VEGETABLES. Calif. Agr. Expt. Sta. Bul. 773, 65 pp.

(5) HARRIS, C. M., PORTER, F. M., and HARVEY, J. M.
1969. MARKET QUALITY AND PRECOOLING RATES OF STRAWBERRIES PACKED IN VARIOUS CONTAINERS. U.S. Dept. Agr. Mktg. Res. Rpt. 851, 5 pp.

(6) HARVEY, J. M.
1961. TIME AND TEMPERATURE EFFECTS ON PERISHABLES SHIPPED BY AIR. Fifth Conf. Transportation of Perishables Proc., Univ. Calif., Davis, Mar. 28–29, 1961, pp. 56–64.

(7) ———
1967. PERISHABLES TRANSPORTATION: AIR SHIPMENT OF STRAWBERRIES. Seventh Fruit and Veg. Perishables Handling Conf. Proc., Univ. Calif., Davis, Mar. 20–22, 1967, pp. 64–69.

(8) ———
1968. USDA STUDIES AIR SHIPMENTS OF CALIFORNIA BERRIES TO EUROPE. The Packer 75(15): 4B, Apr. 27, 1968. (Also published as: Strawberries to Europe by air. Special packaging and containers help maintain quality. United Fresh Fruit and Veg. Assoc. Yearbook 1969: 32, 34, 36.)

(9) ——— COUEY, H. M., HARRIS, C. M., and PORTER, F. M.
1966. AIR TRANSPORT OF CALIFORNIA STRAWBERRIES: FACTORS AFFECTING MARKET QUALITY IN SUMMER SHIPMENTS—1965. U.S. Dept. Agr. Mktg. Res. Rpt. 751, 12 pp.

(10) ——— COUEY, H. M., HARRIS, C. M., and PORTER, F. M.
1966. AIR TRANSPORT OF CALIFORNIA STRAWBERRIES: FACTORS AFFECTING MARKET QUALITY IN SPRING SHIPMENTS—1966. U.S. Dept. Agr. Mktg. Res. Rpt. 774, 9 pp.

(11) ——— HARRIS, C. M., and COUEY, H. M.
1967. EXPORT OF CALIFORNIA STRAWBERRIES TO EUROPE VIA JET AIRFREIGHTER—1966–1967. U.S. Dept. Agr. Mktg. Res. Rpt. 810, 10 pp.

(12) WELLS, J. M.
1968. GROWTH OF RHIZOPUS STOLONIFER IN LOW-OXYGEN ATMOSPHERES AND PRODUCTION OF PECTIC AND CELLULOLYTIC ENZYMES. Phytopathology 58: 1598–1602.

(13) ——— and UOTA, M.
1970. GERMINATION AND GROWTH OF FIVE FUNGI IN LOW-OXYGEN AND HIGH-CARBON DIOXIDE ATMOSPHERES. Phytopathology 60: 51–53.

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